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MARBLE AS A MATERIAL FOR THE PRODUCTION OF BRACELETS IN NEOLITHIC CENTRAL EUROPE

During the study of the Neolithic extraction and distribution of stone raw materials, attention is traditionally focussed on siliceous rocks (sedimentary non-clastic silica-rich rocks, in archaeological papers usually called in a simplified way as flints). A great deal of work has already been done in this area and inventories of prehistoric mining works of a pan-European scope have also been compiled (**fig. 1**; Weisgerber 1981; Kobyliński / Lech 1995; Gayck 2000). Although much less is known thus far about non-siliceous materials, important discoveries have been made in recent years, both in Western (Pétrequin / Gauthier / Pétrequin 2017) and Central Europe (Přichystal 2013). On the one hand, this situation is the result of the research tradition, on the other, the methodological complications associated with the study of non-siliceous material, especially the necessity of using petrographic and geochemical methods. In general, however, petroarchaeology (archaeometry) is an ideal platform for an interdisciplinary dialogue, and we can expect the study of non-siliceous rocks to yield important results in the future.

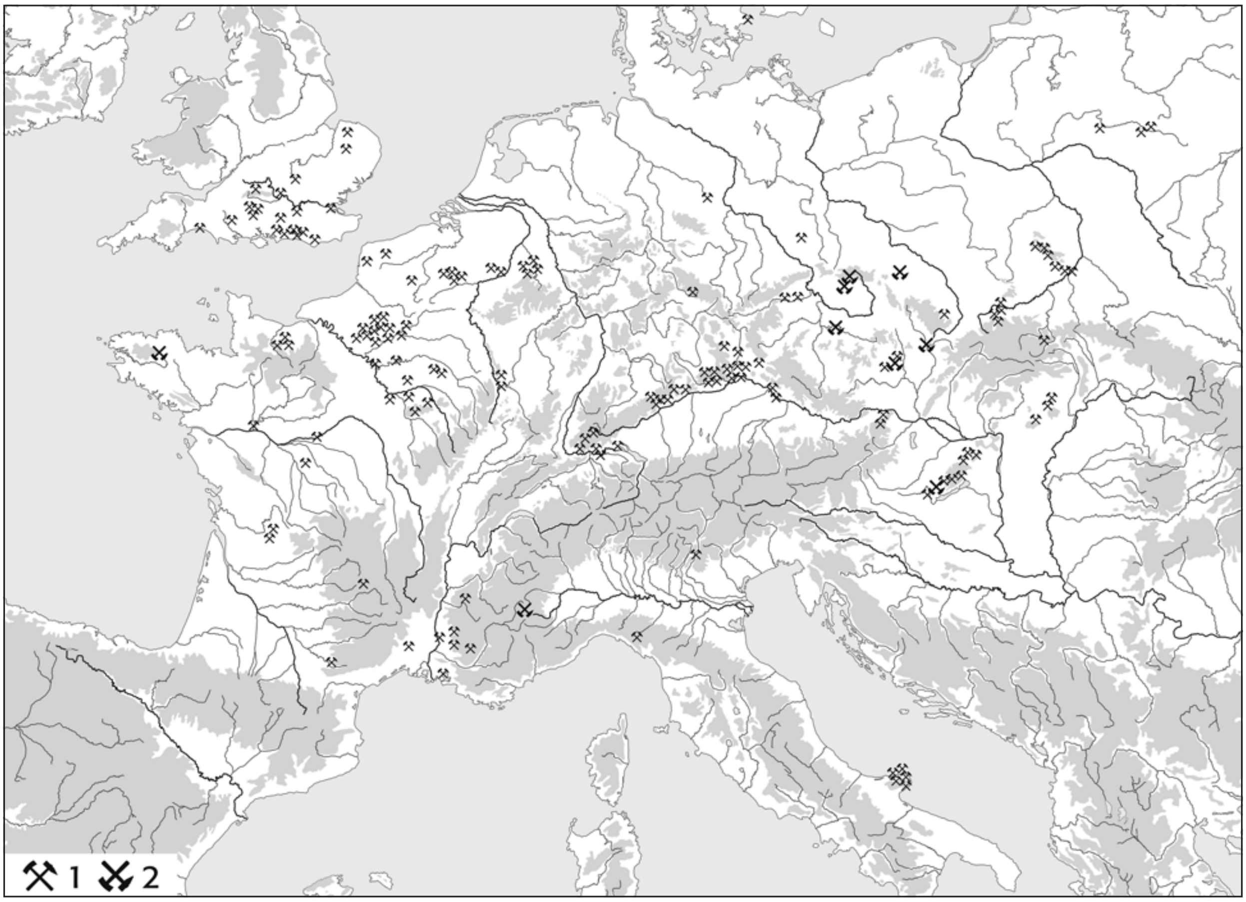


Fig. 1 Evidence of Neolithic extraction of stone material in Central Europe: **1** siliceous rocks (flint, cherts). – **2** non-siliceous rocks. – (Compiled after Weisgerber 1981; Kobyliński / Lech 1995; Gayck 2000; Přichystal 2013 and the authors' database).

Fig. 2 Example of a marble bracelet – early find from the Kolín site (okr. Kolín/CZ). – (Photo I. Herichová). – Scale 1:1.

One seemingly suitable stone material for the study of extraction and distribution is marble. Considering the number of finds, this is a marginal raw material in our studied period of the Late Neolithic (Middle Neolithic in the German chronology). Nevertheless, the potential territorial scope of distribution is considerable. This article focusses on marble bracelets (**fig. 2**), the *fossil directeur* of the Stroked Pottery culture in Bohemia and Bavaria (SBK; 5100/5000-4500/4400 BC). In the contemporaneous German environment, they are characteristic of the Rössen culture (RK; 4800-4500 BC; **fig. 3**).

Over the last few years, the study of marble bracelets from the mentioned cultural and spatial area has become the subject of interest of two separate research teams, and the results of modern research have been summarised in several studies (Přichystal/Burgert/Gadas 2019; Ehling/Hoffmann/Wetzel 2020; Burgert/Přichystal/Davidová 2020). Among other things, these works contain comprehensive information about the history of research and the previous study of the origin of the raw material; as such, the following chapter only briefly summarises the main points in the history of research. These will serve as a suitable backdrop, as the aim of this article is to try to determine the main source of raw material for Late Neolithic marble bracelets.

PRELIMINARY ASSUMPTIONS FOR THE STUDY OF THE ORIGIN OF RAW MATERIAL

In the past, the Bílý kámen site outside the town of Sázava (okr. Benešov/CZ) in Central Bohemia played a key role in the search for the origin of the raw material of marble bracelets (**fig. 4**). From a geological perspective, this is a lens of calcite marble in the biotite to sillimanite-biotite paragneiss of the Šternberk-Čáslav Variegated Group on the border of the Kutná Hora Crystalline Unit and Moldanubian Region (**fig. 5**). As such, this group is classified as the Kutná Hora Crystalline Unit in earlier works, while it is already considered as the diverse group of the Moldanubian Region in more recent studies (Kachlík 1999). The area was further thermally impacted by the intrusion of the nearby Central Bohemian Granitoid Pluton and associated small veins penetrating even into the marble body. The rock was also affected tectonically as a result of the presence of dislocations in the continuation of a major Kouřim fault. The top part of the hill has roughly 150 sunken terrain relics (pits) with a diameter of 2-8 m, representing the remains of mining activity (**fig. 6**).

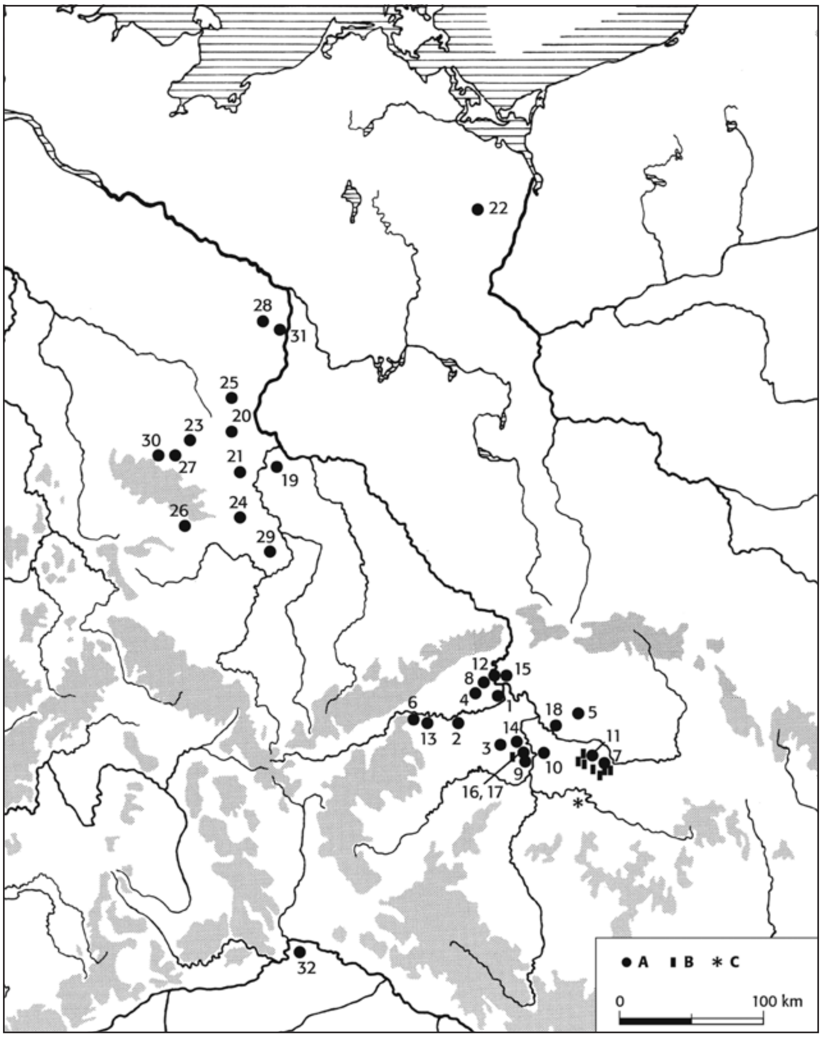


Fig. 3 Finds of marble bracelets and waste-bore plugs in Central Europe: **A** bracelet. – **B** waste-bore plug. – **C** Bílý kámen site (okr. Benešov/CZ). – Locations (bracelets only): **1** Brozany nad Ohří (okr. Litoměřice/CZ). – **2** Březno (okr. Louny/CZ). – **3** Buštěhrad (okr. Kladno/CZ). – **4** Dřemčice (okr. Litoměřice/CZ). – **5** Horky nad Jizerou (okr. Mladá Boleslav/CZ). – **6** Hůrky Dolejší (okr. Louny/CZ). – **7** Kolín (okr. Kolín/CZ). – **8** Lovosice (okr. Litoměřice/CZ). – **9** Praha-Dejvice/CZ. – **10** Praha-Trója/CZ. – **11** Radim (okr. Kolín/CZ). – **12** Velké Žernoseky (okr. Litoměřice/CZ). – **13** Žatec (okr. Louny/CZ). – **14** Černý Vůl/Statenice (okr. Praha-západ/CZ). – **15** Litoměřice (okr. Litoměřice/CZ), without closer localization. – **16** Praha-Sedlec/CZ. – **17** Roztoky (okr. Praha-západ/CZ). – **18** Tišice (okr. Mělník/CZ). – **19** Lkr. Bernburg/D, without closer localization. – **20** Engeln (Lkr. Börde/D). – **21** Groß Schierstedt (Salzlandkreis/D). – **22** Grünow (Lkr. Mecklenburgische Seenplatte/D). – **23** Halberstadt (Lkr. Harz/D). – **24** Helfta (Lkr. Mansfeld-Südharz/D). – **25** Hundisburg (Lkr. Börde/D). – **26** Ichstedt (Kyffhäuserkreis/D). – **27** Langenstein (Lkr. Harz/D). – **28** Peulingen (Lkr. Stendal/D). – **29** Rössen (Saalekreis/D). – **30** Silstedt or Minsleben (Lkr. Harz/D), without closer localization. – **31** Storkau (Lkr. Stendal/D). – **32** Harting (Stadt Regensburg/D). – (Compiled after Zápotocká 1984, figs 9-10, supplemented).

Prague geologist Karel Žebera first drew attention to the site at the end of the 1930s, interpreting it as a prehistoric mining field and connecting the local raw material with the material used to produce Neolithic marble bracelets (Žebera 1939).

The other marbles in the Šternberk-Čáslav Group typically protrude with amphibolites and are dolomitic. Their broader surroundings are formed by biotite-muscovite mica-schist to muscovite-biotite paragneiss (Kodym 1997). Dolomitic marbles are concentrated primarily around the town of Český Šternberk (okr. Benešov/CZ) (**fig. 7**). During the Middle Ages and the Modern Period, they were intensively mined and used as building stone (e.g., on the stairs at the local castle). Apparently as a result of this mining, no traces of prehistoric mining have been found on any of these dolomitic marbles.

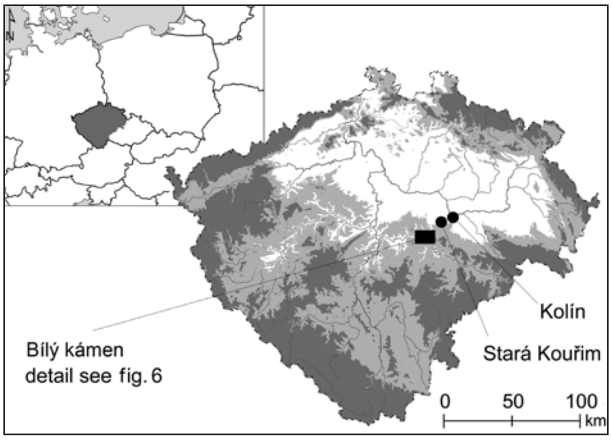


Fig. 4 Localization of the Bílý kámen, Stará Kouřim and Kolín sites mentioned in the text. – (Map. P. Burgert).

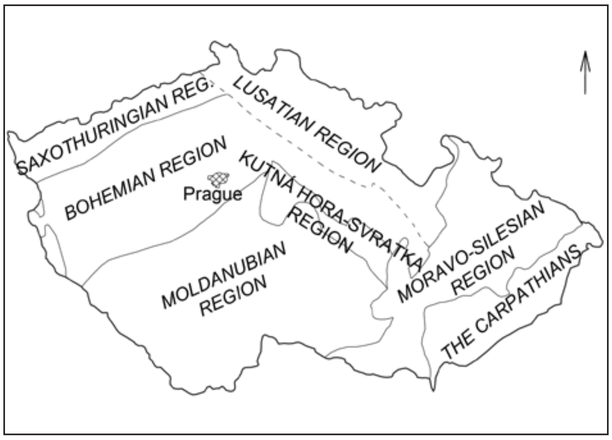


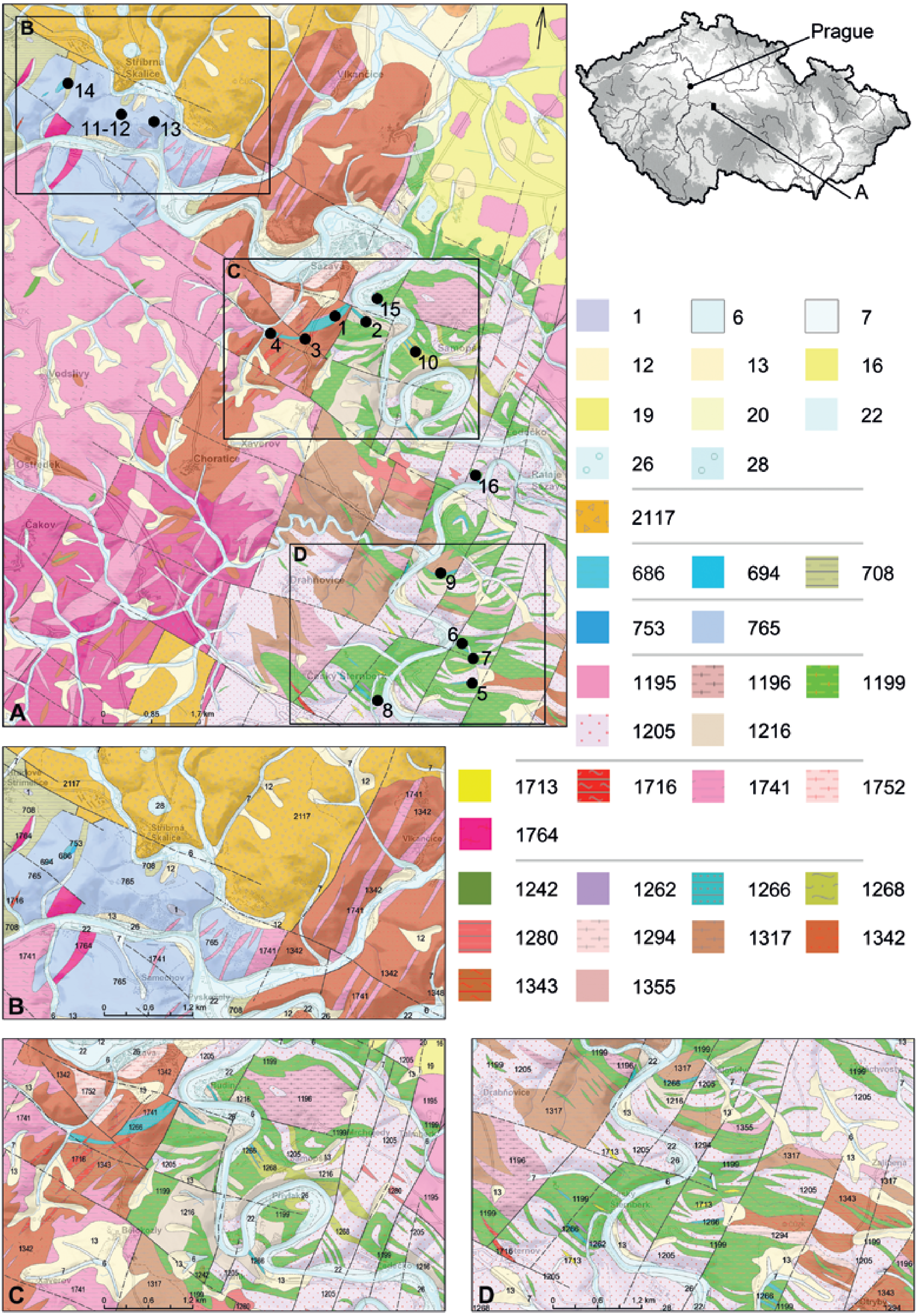
Fig. 5 Division of the Bohemian Massif into basic geological regions. – (After Mísař et al. 1983).

Fig. 6 Terrain relic of mining on the Bílý kámen site. – (Photo P. Burgert).

Another important advance in connection with the mined raw material was the work of Marie Zápotocká, who compiled a catalogue of available bracelet finds in Central Europe (Zápotocká 1984). Zápotocká built on Žebera's original concept and identified the Sázava region as a source area for the raw material used to make marble bracelets, even connecting finds from Halle (Saale) to it. However, it should be noted that in a geological report attached to the work as an appendix, the authors reached a conclusion on a different raw material used to make the artefacts (dolomite to metadolomite marble) compared to calcite marble from Bílý kámen. This conclusion was based on staining tests and X-ray powder diffraction (Březinová/Bukovanská 1984).

After nearly four decades, Bílý kámen marble has once again become the subject of petrographic analysis (Přichystal/Burgert/Gadas 2019). The significant homogeneity of the entire local marble body has been stated. It is pure calcite marble with the accessory presence of silicates (tremolite, phlogopite, muscovite, chlorite) and apatite. This type is rare in the broader Sázava region, where dolomite marbles mostly dominate. Based on current knowledge, it can be stated that Bílý kámen was not the main source of raw material for either the Bohemian (Burgert/Přichystal/Davidová 2020) or German finds (Ehling/Hoffmann/Wetzel 2020). We will attempt to identify the main source of raw material in the following chapters.

Fig. 7 Geological map of the Sázava River region studied in detail: **A** general overview (site numbering corresponds to **tab. 1**). – **B-D** parts with detailed view. – Quaternary: **1** anthropogenic deposits. – **6** alluvial sediment. – **7** polygenetic sediment. – **12** sandy-loamy to loamy-sandy sediment. – **13** loamy sediment with rock debris. – **16. 19** loess and loess loam. – **20** deluvial-aeolian sediment. – **22. 26. 28** sand, gravel. – Upper Carboniferous-Permian: **2117** sandstone, siltstone and conglomerate, intercalations of limestone, claystone, chert, clay carbonate, small coal bed. – Paleozoic to Proterozoic: Bohemicum: **686** crystalline limestone (marble). – **694** erlan. – **708** quartzite and biotite-muscovite phyllite. – **753** limestone. – **765** palaeobasalt, palaeoandesite-basalt, tuff. – Kutná Hora-Svratka Crystalline Unit: **1195** two-mica migmatite to orthogneiss. – **1196** biotite-muscovite orthogneiss. – **1199** amphibolite. – **1205** two-mica schist. – **1216** two-mica gneiss to biotite paragneiss with amphibole. – **1713** aplite, pegmatite, aplopegmatite with tourmaline. – **1716** vein granite. – **1741** fine-grained two-mica to biotite granite. – **1752** granite (Kšely type). – **1764** granodiorite (Benešov type). – **1242** serpentinite. – **1262** erlan. – **1266** calcite and dolomite marbles. – **1268** quartzite, paragneiss. – **1280** orthogneiss to metagranite. – **1294** orthogneiss. – **1317** migmatite. – **1342-1343. 1355** paragneiss. – (Adapted according to www.geology.cz [2.2.2022], Geoscience maps, Geological Map of the CR 1:50,000).



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Stříbrná Skalice
Vlkančice
Sázava
Samopše
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Choratice
Ostředek
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Drahňovice
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Fig. 8 Examples of waste-bore plugs from the Stará Kouřim and Kutná Hora (smallest) sites. – (Photo L. Vojtěchovský). – Scale 1:2.

METHODOLOGY

The work is based on a detailed petrographic and geochemical analysis of marble occurrences from the area between Český Šternberk and Sázava (**fig. 7**). Support for this being the source area is the proximity of workshops in the Kouřim and Kolín regions, where the marble was worked into bracelets (**fig. 4**). These workshops are already situated at the southern edge of the Bohemian Cretaceous Basin, which is composed of unmetamorphosed sedimentary rock, where marble could not occur. For comparison, we also tentatively analysed marbles from the surrounding geological units of the Moldanubian Region (Moldanubicum) and Central Bohemian Region (Bohemicum), and the more distant Lusatian Region (Lugicum) and the northern part of the Moravo-Silesian Region (Silesicum). Certain marbles (white and black banded, ochre-coloured) could already be ruled out on the basis of a macroscopic comparison with the material of the bracelets and the plugs removed in their production (**fig. 8**). It is uniformly coloured, yellowish or brownish white-grey in a patinated state, sugar-white on a fresh cut, always grainy to the naked eye. Petrographic sections taken from natural sources were studied by Antonín Přichystal under a polarizing microscope and the chemistry of individual minerals was determined with the help of an electron microprobe (operator Petr Gadas from the Institute of Geological Sciences, Faculty of Science, Masaryk University in Brno). The chemical composition of marble from natural source Bílý kámen was determined after crushing and homogenising the rocks at the Bureau Veritas Laboratory, Vancouver, Canada, analytical package LF200 (for details see www.acmelab.com [2.2.2022]). The chemistry of the artefacts was monitored using non-destructive ED-XRF analyses, while at the same time being checked by measuring marble analysed by classical methods in Canada. The mineral composition was determined for key sources and some artefacts by X-ray diffraction (XRD) analysis with an estimation of quantitative representation using the Rietveld method (performed by Dalibor Všianský from the Institute of Geological Sciences, Faculty of Science, Masaryk University in Brno). The density of all examined marble (natural resources, artefacts) was measured using a non-destructive method.

THE STUDY OF THE RAW MATERIALS OF BRACELETS AND WASTE-BORE PLUGS

Table 1 summarises all of the studied artefacts, i.e., a total of 17 specimens from the Central Bohemian Region. Macroscopically, the marble of all artefacts was characterised by a homogeneous structure, i.e., without the presence of either black (graphitic) or ochre (iron-coloured compounds) bands. Waste-bore plugs, which were not smoothed, are more heavily weathered, which accentuates the granularity of the rock (carbonate grains range in size from tenths of mm up to 1-2 mm) and the metamorphic foliation, which is mostly parallel to the base of the waste-bore plugs (in one rare case it is almost perpendicular to it). As the colour of the rock was influenced by long-term deposition in archaeological features, the surface of the plugs is typically a brownish white, while if a fresh fracture was apparent, the colour was sugar-white. Due to the lack of smoothed places, they could not be investigated using non-destructive XRD analysis. However, small fragments could be obtained from several of them and the analyses were performed on their powder preparations.

		density (g/cm³)	estimation of mineral composition based on XRD	classification of the rock
	artefacts			
	Praha-Trója NM 83422 (bracelet)	2.82	97.7 % Dol, 2.3 % Cal	dolomite marble
	Praha-Trója NM 83423 (bracelet)	2.70		calcite marble
	Brozany NM 45285 (bracelet)	2.82		dolomite marble
	Radim NM 60566 (waste-bore plug)	2.84	94.5 % Dol, 5.5 % Cal, < 0,1 % Qtz	dolomite marble
	Radim NM 60567 (waste-bore plug)	2.83		dolomite marble
	Praha-Dejvice MMP A1719 (waste-bore plug)	2.71	99.9 % Cal, <0,1 % Qtz	calcite marble
	Praha-Dejvice MMP A1720 (bracelet)	completed by gyps	64.5 % Dol, 31.8 % Cal, 3.7 % Qtz	dolomite-calcite marble
	Praha-Dejvice MMP A1721 (bracelet)	completed by gyps	84.5 % Dol, 12 % Cal, 1.5 Qtz, 1.6 Tlc, 0.4 Kln	dolomite marble
	Praha-Dejvice MMP A1722 (bracelet)	completed by gyps	60 % Dol, 40 % Cal	dolomite-calcite marble
	Stará Kouřim NM 3981 (waste-bore plug)	2.83	87.6 % Dol, 8.9 % Cal, 1.7 % Chl?, 0.8 % Am, 0.3 % Ms, 0.3 % Tlc, 0.1 % Qtz, Phl, Py?	dolomite marble
	Stará Kouřim NM č. 2 (waste-bore plug)	2.81	91.5 % Dol, 3.6 % Tlc, 3 % Chl?, 1.2 % Cal, 0.7 % Qtz	dolomite marble
	Stará Kouřim NM č. 5 (waste-bore plug)	2.78	96 % Dol, 3 % Chl?, 1 % Tlc	dolomite marble
	Stará Kouřim NM č. 11 (waste-bore plug)	2.80	71 % Dol, 18.1 % Cal, 5.8 % Am, 2.3 % Tlc, 1.8 % Chl (Smectite?), 1 % Mica	dolomite marble
	Stará Kouřim NM č. 27 (waste-bore plug)	2.83	74.2 % Dol, 8.8 % Cal, 7.6 Am, 4.3 % Tlc, 3.6 Chl?, 1.5 Qtz	dolomite marble
	Třebovle u Kouřimi NM 15660 (waste-bore plug)	2.83		dolomite marble
	Třebovle u Kouřimi NM 15716 (waste-bore plug)	2.81		dolomite marble
	Kutná Hora (waste-bore plug)	2.78		dolomite marble (?)
see fig. 7	raw materials			
	1. area of the Sázava River			
1	Bílý kámen 2017/1	2.68	99.4 % Cal, 0.6 % Qtz	calcite marble
1	Bílý kámen 2017/2	2.69	98.8 % Cal, 1.2 % Gr?	calcite marble
1	Bílý kámen 2017/5	2.70	95.1 % Cal, 0.1 % Dol, 3.7 % Qtz, 0.9 % Chl?, 0.2 % Py?	calcite marble
1	Bílý kámen 2017/6	2.69	97.7 % Cal, 1.2 % Chl?, 0.7 Dol, 0.4 Qtz	calcite marble

Tab. 1 Densities and mineral composition of marble artefacts from Central Bohemia and marble natural sources in the Bohemian Massif. Abbreviations of minerals: Cal: calcite. – Dol: dolomite. – Qtz: quartz. – Chl: chlorite. – Am: amphibole. – Tlc: talc. – Kln: kaolinite. – Phl: phlogopite. – Ms: muskovite. – Or: orthoclase. – Py: pyrite. – Gr: graphite. – Sd: siderite. – Smectite: montmorillonite and other swelling clay minerals. – Mica: mica structure minerals. – Ank: ankerite. – Sp: spinel. – Hem: hematite. – Grs: grossular. – Wo: wollastonite. – Di: diopside. – Ves: vesuvianite. – Or: orthoclase.

		density (g/cm³)	estimation of mineral composition based on XRD	classification of the rock
1	Bílý kámen 2019/1 (roughout from mining pit)	2.68		calcite marble
1	Bílý kámen 2019/2 (roughout from mining pit)	2.73		calcite marble
1	Bílý kámen 2019/3 (roughout from mining pit)	2.68		calcite marble
1	Bílý kámen 2019/16	2.71	98.7 % Cal, 1.3 % Qtz	calcite marble
2	Bílý kámen 2019/17	2.83	84.9 % Dol, 9.1 % Cal, 3.6 Chl?, 1.3 % Talc, 1.1 % Am	dolomite marble
3	Bělokozly east 2019/14	2.70	96.7 % Cal, 3 % Qtz, 0.3 % Sd	calcite marble
4	Bělokozly west 2019/15	2.70	99.5 % Cal, 0.5 % Qtz	calcite marble
15	Samopše-Budín 2019/18	2.69	96.4 % Cal, 1.5 % Qtz, 1.1 % Dol, 0.8 % Chl (Smectite?), 0.2 % Mica	calcite marble
10	Samopše 2019/25	2.83	88.3 % Dol, 7.1 % Cal, 3.2 % Chl?, 0.5 % Mica, 0.3 Qtz	dolomite marble
9	Malovidy 2019/22	2.81	78.1 % Dol, 12.5 % Cal, 4.4 % Am, 2.3 Chl?, 1.6 Tlc, 1.1 Mica	dolomite marble
16	Rataje 2019/24	2.83	83.8 % Dol, 9.8 % Cal, 1.8 % Tlc, 1.5 % Chl?, 1.5 % Am, 1.3 % Mica, 0.3 % Qtz	dolomite marble
5	Český Šternberk-Nový Dvůr 2019/11	2.77	82.3 % Dol, 13.4 % Cal, 2.2 % Chl?, 1 % Tlc, 0.5 % Py, 0.4 % Pl, <0,1% Am, Qtz, Phl	dolomite marble
6	Český Šternberk Na Stříbrné A 2019/12	2.84	89.3 % Dol, 4.8 % Cal, 3.2 % Tlc, 1.6 % Chl?, 0.8 % Mica, 0.3 % Kln	dolomite marble
7	Český Šternberk Na Stříbrné B 2019/13	2.86	91.4 % Dol, 4 % Cal, 1.8 % Mica, 1.7 % Chl?, 0.9 % Tlc, 0.2 % Kln	dolomite marble
8	Český Šternberk, U hladomorny	2.71	96 % Cal, 3.6 % Qtz, 0.4 % Smectite (+ Chl?)	calcite marble
11	Stříbrná Skalice-Homole A	2.69	98.8 % Cal, 1.2 % Ank	calcite marble
12	Stříbrná Skalice-Homole B	2.71	100 % Cal	calcite marble
13	Stříbrná Skalice-Čapík	2.68	99.9 % Cal, 0.1 % Qtz	calcite marble
14	Stříbrná Skalice-Žežule	2.70	100 % Cal	calcite marble

Tab. 1 Continued.

		density (g/cm³)	estimation of mineral composition based on XRD	classification of the rock
see fig. 9	2. Bohemian Massif, central and southern parts (Moldanubicum, Kutná Hora-Svratka Crystalline Unit, Bohemicum)			
19	Bohdaneč (okr. Kutná Hora), Central Bohemia	2.84	81.8 % Dol, 10.8 % Cal, 2.6 % Am, 2.4 % Mica, 1.7 % Chl?, 0.7 % Gr?	dolomite marble
18	Krty (okr. Strakonice), SW Bohemia	2.70	90.8 % Cal, 3.5 % Ank, 3 % Dol, 2.2 % Chl, 0.4 % Qtz, <0.1 % Mica	calcite marble
17	Chýnov (okr. Tábor), South Bohemia	2.78	81.7 % Cal, 14.6 % Qtz, 2.4 % Am, 1.3 % Tlc	calcite marble
24	Zblovice (okr. Znojmo), SW Moravia	2.73	91.6 % Cal, 6.1 % Dol, 1.3 % Chl?, 0.3 % Tlc, 0.4 % Sp, 0.2 Am, <0.1 % Mica, Hem	calcite marble
25	Nedvědice (okr. Brno-venkov), South Moravia	2.84	85.8 % Cal, 6.7 % Grs, 4 % Di, 1.8 % Wo, 1.6 % Ves, <0,1 % Or	calcite marble with silicates
20	Prachovice (okr. Pardubice), East Bohemia	2.72	99.5 % Cal, 0.5 % Mica	Devonian limestone
see fig. 9	3. Bohemian Massif, northern part (Lugicum, Silesicum)			
21	Paseky nad Jizerou (okr. Semily), North Bohemia	2.70	100 % Cal	calcite marble
22	Rejdice (okr. Jablonec nad Nisou), North Bohemia	2.81	69.2 % Dol, 18.9 % Cal, 9.8 % Qtz, 1.8 % Chl?, 0.3 % Mica	dolomite marble
23	Horní Albeřice (okr. Trutnov), North Bohemia	2.70	98.1 % Cal, 1.1 % Qtz, 0.6 % Dol, 0.2 % Mica	calcite marble
27	Králický Sněžník (okr. Ústí nad Orlicí), NE Bohemia	2.69	97.6 % Cal, 1.3 % Chl + Smectite, 0.7 % Dol, 0.3 % Kln, 0.1 % Qtz, <0.1 % Mica	calcite marble
26	Supíkovice (okr. Jeseník), Czech Silesia	2.69	92.1 % Cal, 6.6 % Dol, 0.9 % Chl, 0.4 % Mica	calcite marble

Tab. 1 Continued.

The smoothed bracelets were often covered with secondarily precipitated carbonates or iron hydroxides, and their long-term deposition in the soil also impacted their colour. For exhibition purposes, many of them were supplemented in their entire form with artificial material, making it impossible to determine their density. That is why only density is determined for some artefacts, for others only their mineral composition by X-ray diffraction.
Since earlier studies of marble artefacts from the Czech Republic described in several cases secondary fluorescence after irradiation with an UV lamp (Mrázek 1996, 40), this method was also applied on the studied artefacts. Of all the artefacts, only two plugs from Radim (okr. Kolín/CZ) showed short-term fluorescence, which indicates a somewhat different material than the others.

Determining the Density and Mineral Composition of the Rock from Which the Artefacts Are Made

The method of comparison based on measured density has proven to be very useful, as it is non-destructive, fast and inexpensive. In addition, the geological literature offers a clear database of marble densities from various units of the Bohemian Massif (Eliáš/Uhmann 1968). Their results show that this method can be used to clearly distinguish calcite marbles from dolomite marbles, since the density of calcite marbles from the core of the Bohemian Massif (22 samples) were in the range of 2.70-2.77 g/cm^3, similar to the Western Sudetes (51 samples; average of 2.73 g/cm^3), whereas dolomite marbles either from the crystalline basement of NW Bohemia (10 samples) or from the Western Sudetes (20 samples) had substantially higher values (2.81-2.84 g/cm^3). Our samples from natural sources yielded the same results with only one exception – blue calcite marble from Nedvědice (okr. Brno-venkov/CZ) with a density of 2.84 g/cm^3. The anomalous density is caused by a high presence of silicate minerals.
A look at our results (**tab. 1**) shows that the raw material of all unweathered plugs from workshops near Stará Kouřim (okr. Kolín/CZ) is almost identical (2.82-2.84 g/cm^3) and clearly corresponds to dolomite marbles, with only a plug from Kutná Hora (okr. Kutná Hora/CZ) (2.78 g/cm^3) differing slightly on the border between dolomite and calcite marble. Like the plugs from the workshops near Stará Kouřím, it is necessary to bear in mind with this plug that it is not suitable for determining the density due to its heavily honeycomb-weathered surface with hidden miniature air bubbles, which reduce the density. This idea was confirmed on the large plug Stará Kouřim no. 3981, from which we removed unweathered rock and compared the density of the entire weathered artefact (2.78 g/cm^3) with this fresh sample (2.83 g/cm^3). It is therefore necessary to take the determined density of plugs from Stará Kouřim as approximations, even after recalculation by a factor of 1.018, which we obtained from sample no. 3981. XRD analyses showed that this was marble with a very high content of dolomite and the presence of talc.
X-ray diffraction analyses were performed on the smoothed surfaces of the bracelets from Prague-Trója and Prague-Dejvice, and from some plugs (Stará Kouřim, Radim) we studied a small amount of powder by X-ray diffraction, which also confirmed that they were dolomite marbles. In any case, the assemblage of plugs from Stará Kouřim gives a very homogenous impression, suggesting that they come from a single source.
In a rare case, we recorded a plug made from calcite marble both by density and X-ray diffraction. The site in question was Prague-Dejvice (no. A1719). While X-ray analyses indicate that certain bracelets from the same site are predominantly dolomite, the rate is not as high as at the source in Český Šternberk-Na Stříbrné. It therefore seems probable that more bodies of dolomite marbles in the vicinity of Český Šternberk could have served as sources for the production of bracelets.

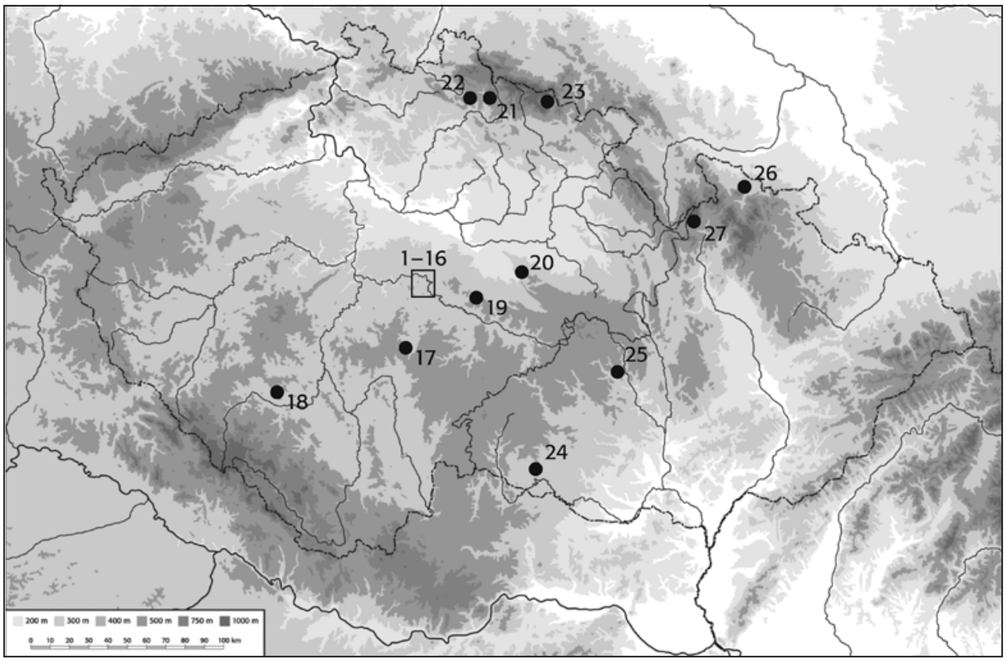

Fig. 9 Studied outcrops of raw material (site numbering corresponds to **tab. 1**): **1-16** see **fig. 7**. – **17** Chýnov (okr. Tábor/CZ). – **18** Krty (okr. Strakonice/CZ). – **19** Bohdaneč (okr. Kutná Hora/CZ). – **20** Prachovice (okr. Pardubice/CZ). – **21** Paseky nad Jizerou (okr. Semily/CZ). – **22** Rejdice (okr. Jablonec nad Nisou/CZ). – **23** Horní Albeřice (okr. Trutnov/CZ). – **24** Zblovice (okr. Znojmo/CZ). – **25** Nedvědice (okr. Brno-venkov/CZ). – **26** Supíkovice (okr. Jeseník/CZ). – **27** Králický Sněžník (okr. Ústí nad Orlicí/CZ). – (Map P. Burgert).

Determining the Density and Mineral Composition of the Marbles from Potential Sources

Figure 9 shows the overall localisation of our studied natural sources of marbles; a listing of them is provided in **table 1**. This concerns 23 samples from the broader Posázaví region (**fig. 7**). This assemblage is supplemented with another 11 potential sources located outside this region.

First, it is necessary to present the densities and mineral composition of the marble from the site that interested us the most – the top of the hill Bílý kámen near Sázava with traces of prehistoric and medieval marble extraction. The first data from the analysis of the natural source has already been published (Přichystal/Burgert/Gadas 2019). The density was determined to be 2.68-2.71 g/cm^3. Three bracelet roughouts acquired during an archaeological excavation of an extraction field at this site in 2019 were then included (Burgert/Přichystal/Davidová 2020). Their density was determined to be 2.68-2.73 g/cm^3.

These data confirm that the entire ridge part of Bílý kámen has a homogeneous group of densities, which are clearly characteristic of calcite marbles. We then determined the density for the continuation of the marble lens from Bílý kámen to the SW, which is already located in the town of Bělokozly (okr. Benešov/CZ) (two samples from the eastern and western part had the identical value of 2.70 g/cm^3). It is therefore clear that according to the densities, the entire marble body on Bílý kámen, including its continuation in the cadastre of Bělokozly, is made of calcite marble (confirmed by XRD analyses) and thus does not correspond to the densities of dolomite marbles forming the raw material of the vast majority of the studied plugs and bracelets.

Other values were provided by marbles taken from the east and especially from the southeast of Bílý kámen, i.e., in the broader valley of the Sázava River towards Český Šternberk (**fig. 7**). The closest different sample was found in a quarry above the railway line from Sázava to the village of Samopše (okr. Kutná Hora/CZ), about 700 m east of the peak of Bílý kámen (Bílý kámen sample 2019/17), the density of which was 2.83 g/cm^3. The high content of 85 % dolomite was also confirmed by XRD analysis. Hence, this is a different body of marble, since further from Samopše towards Český Šternberk there are only dolomite marbles with similar densities. We studied marble near the railway stop in Samopše, which had a value of 2.83 g/cm^3, marble from Malovidy (okr. Benešov/CZ) (2.81 g/cm^3) and especially from around Český Šternberk-Nový Dvůr (2.77 g/cm^3) and the Na Stříbrné quarry (2.84-2.86 g/cm^3). The density of the marble from the Na Stříbrné quarry in particular overlaps considerably with the densities of the artefacts, and the marble is also macroscopically very similar to it. The high proportion of dolomite (89-91 %) determined by XRD analysis also closely corresponds to the values found on the plugs from Stará Kouřim (88-91 % dolomite). The results therefore confirm our previously published hypothesis that calcite marble from the peak of Bílý kámen is exceptional in this part of the Posázaví region, as dolomite marble completely dominates the area north of Český Šternberk. The lone determined exception is a small marble body at Český Šternberk »U hladomorny« composed of calcite marble (**fig. 7**).

CONCLUSION

Contrary to expectations, a detailed mineralogical analysis of marble bracelets in the environment of the Stroked Pottery culture produced surprising conclusions. The presented results show that the body of calcite marble at the Bílý kámen site near the town of Sázava was not the main source of material for these bracelets as previously assumed. The waste-bore plugs from their production in Neolithic workshops in Stará Kouřim and Radim near Kolín all come from a different material – highly grainy dolomite marble. The vast majority of the studied bracelets (Prague-Trója, Prague-Dejvice) are made also from dolomite marble. According to the current state of information, bracelets and waste-bore plugs from calcite marble are rare. Nevertheless, the origin of this small part of the finds at Bílý kámen is likely.

But given the localisation of prehistoric workshops in the neighbouring settlement region, the Sázava River region still remains highly probable. For this reason, we conducted an in-depth study of marble sources in this region, which confirmed the occurrence of dolomite marbles around Český Šternberk. Their macroscopic properties (visible grain size), their densities, the high proportion of dolomite and the presence of talc closely correspond to the raw materials of the final bracelets and the raw material from the workshops for their production. However, unlike the situation at Bílý kámen, traces of prehistoric extraction of the material have not been reliably proven thus far at any of these newly analysed bodies.

Working with our data, we can attempt to pinpoint the main source of the material. We can rule out the high-quality marble from nearby Stříbrná Skalice as a potential source, as it differs both in its density and mineral composition (calcite marble). Marble from Bohdaneč is worthy of attention, the qualities of which could correspond to several artefacts; however, it does not contain talc. A look at the sources of marbles in other geological units of the Bohemian Massif reveals that none of them meets the properties consistent with the raw materials of the artefacts, the vast majority of which are made from calcite marbles. Although the marble from Rejdice is a dolomite marble, it does not contain talc. Marbles from the northern geological units of the Bohemian Massif (Lusatian Region – Lugicum; Moravo-Silesian Region – Silesicum) mostly differ already by the macroscopic presence of bands coloured with dark graphite (Králický Sněžník [okr. Ústí nad Orlicí/CZ), Supíkovice [okr. Jeseník/CZ]) or bands coloured by compounds of iron (Horní Albeřice [okr. Trutnov/CZ]), and they are calcitic. Marble from Nedvědice is exceptional in that while its density corresponds to dolomite marble, it is composed of extremely deformed calcite, which is also blue in colour.

Based on a comparison of natural marble outcrops in the central Sázava River region with the material of bracelets and waste-bore plugs from the environment of the Stroked Pottery culture, the current state of knowledge points to Český Šternberk-Na Stříbrné (**fig. 7**, 6-7) or the Samopše site (**fig. 7**, 10) as the main source of the material. Both of these sources are composed of high-quality dolomite marbles containing talc.

Finally, it would be interesting to compare this finding with a second area of the occurrence of marble bracelets – the contemporary environment of the Rössen culture. Their raw materials were last studied by a team of authors using infrared spectroscopy (Ehling / Hoffmann / Wetzel 2020). In the past, it was quite logically assumed that they also came from Bílý kámen in Central Bohemia (Zápotocká 1984). While many of these artefacts are made from material with a high representation or predominance of dolomite, it also contains 20-40 % of magnesite. However, marbles of this type are not known in the Sázava River region or anywhere else in the Bohemian Massif. As such, the origin of the majority of bracelets from east Germany will have to be sought elsewhere. Unlike the situation in Bohemia, the fact that we do not encounter evidence of their production in the environment of the Rössen culture seems problematic. It is remarkable from an archaeological perspective that massive marble bracelets occur at the same time in two different places in culturally very similar environments, while the distribution scheme of their raw material is clearly different.

Funding

The research described in this paper was accomplished with support from the project »Marble as a raw material in the Neolithic jewels of Central Europe« (Project 19-04121S), financed by the Czech Science Foundation.

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Zusammenfassung / Summary / Résumé

Marmor als Material für die Herstellung von Armringen im neolithischen Mitteleuropa

Marmorarmringe sind charakteristische Artefakte der Stichbandkeramik-Kultur (5100/5000-4500/4400 v. Chr.) in Mittelböhmen; im gleichen Zeithorizont treten sie auch im Bereich der Rössener Kultur an der Saale in Deutschland auf. Diese Funde zogen seit dem 19. Jahrhundert das Interesse auf sich, und die Frage nach der Herkunft ihres Materials galt seit mehreren Jahrzehnten geklärt. Eine neue mineralogische Untersuchung hat jedoch gezeigt, dass die Hauptquelle des Materials an anderer Stelle zu lokalisieren ist und dass die Gesamtzahl der genutzten Marmorvorkommen höher war. In diesem Artikel werden die Ergebnisse der Untersuchung der Artefakte und die Befunde aus einer Geländeuntersuchung der vielversprechendsten natürlichen Vorkommen des Materials in der Tschechischen Republik vorgestellt. Die Kombination dieser beiden Ansätze hat zur Entdeckung der wichtigsten möglichen Quelle geführt.

Marble as a Material for the Production of Bracelets in Neolithic Central Europe

Marble bracelets are a characteristic artefact of the Stroked Pottery culture (5100/5000-4500/4400 BC) in Central Bohemia, and they also occur in the same period in the sphere of the Rössen culture around the River Saale in Germany. These finds began to attract interest in the 19th century and the issue of the origin of their material had been considered resolved for several decades. However, a new mineralogical study has shown that the main source of material was located elsewhere and that the overall number of sources used was higher. The article presents the results of the study of the actual artefacts and the results of a terrain survey of the most promising natural sources of the material in the Czech Republic. The combination of the two approaches led to the discovery of the main potential source.

Le marbre: une roche servant à fabriquer des bracelets au Néolithique en Europe centrale

Le bracelet de marbre est un artefact caractéristique de la culture à Céramique pointillée (5100/5000-4500/4400 av. J.-C.) de la Bohème centrale et apparaît à la même époque dans la sphère d'influence de Rössen du bassin de la Saale en Allemagne. Ces objets commencèrent à attirer l'attention au 19e siècle et l'on pensait avoir résolu depuis plusieurs décennies le problème de l'origine de la roche utilisée. Mais, une récente étude minéralogique révèle que le gisement principal de cette roche se situe ailleurs et que la quantité globale des gisements utilisés était plus élevé. Cet article présente les résultats de l'étude des artefacts existants et ceux d'une prospection des gisements les plus prometteurs de la République tchèque. La combinaison des deux approches a permis d'identifier le principal gisement potentiel.

Traduction: Y. Gautier

Schlüsselwörter / Keywords / Mots-clés

Neolithikum / Stichbandkeramik-Kultur / Rössener Kultur / Marmor / Armring / Verteilung / Bergbau
Neolithic period / Stroked Pottery culture / Rössen culture / marble / bracelet / distribution / mining
Néolithique / culture à Céramique pointillée / culture de Rössen / marbre / bracelet / distribution / extraction

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